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Report No. CG-D-08-01

ENERGY SAVING ALTERNATIVES FOR U.S. COAST GUARD (USCG) BOATS

FINAL REPORT
JANUARY 2001

Prepared for:

U.S. Department of Transportation
United States Coast Guard
Finance and Procurement Directorate
Washington, DC 20593-0001

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Technical Report Documentation Page

1. Report No. CG-D-08-01	**2. Government Accession Number** ADA 392246	**3. Recipient's Catalog No.**
4. Title and Subtitle Energy Saving Alternatives for U.S. Coast Guard (USCG) Boats		**5. Report Date** January 2001 **6. Performing Organization Code** Project No. 9207.7
7. Author(s) David Pogorzelski, Elbert G. Adamos		**8. Performing Organization Report No.**
9. Performing Organization Name and Address Naval Surface Warfare Center Carderock Division-Norfolk Division 116 Lake View Parkway, Suite 200 Suffolk, VA 23435-2698	U.S. Coast Guard Research and Development Center 1082 Shennecossett Road Groton, CT 06340-6096	**10. Work Unit No. (TRAIS)** **11. Contract or Grant No.** MIPR: DTCG39-99-X-E00253
12. Sponsoring Organization Name and Address U.S. Department of Transportation United States Coast Guard Finance and Procurement Directorate Washington, DC 20593-0001		**13. Type of Report & Period Covered** Final **14. Sponsoring Agency Code** Commandant (G-CFP) U.S. Coast Guard Headquarters Washington, DC 20593-0001

15. Supplementary Notes

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16. Abstract (MAXIMUM 200 WORDS)

An examination of technical and procedural approaches to reducing energy usage and cost was performed to determine applicability to U.S. Coast Guard (USCG) boats and small cutters. A detailed cost-benefit analysis was conducted for those approaches deemed feasible for possible retrofit. Payback period and annual fuel savings were calculated to provide guidance to the USCG regarding which approaches should be pursued for incorporation in the fleet.

17. Key Words fuel, consumption, cutter, boat, technology, energy	**18. Distribution Statement** This document is available to the U.S. public through the National Technical Information Service, Springfield, VA 22161

19. Security Class (This Report) UNCLASSIFIED	**20. Security Class (This Page)** UNCLASSIFIED	**21. No of Pages**	**22. Price**

Form DOT F 1700.7 (8/72) Reproduction of form and completed page is authorized

Executive Summary

Rising energy costs have created a budget crisis within the United States Coast Guard. Non-essential operations, including vessel training, have been curtailed because fuel has become so expensive. Reducing energy consumption has become a high priority for the entire fleet. In response to this problem, the Coast Guard R&D Center tasked the Naval Surface Warfare Center, Carderock Division, Detachment Norfolk, Combatant Craft Department (CCD) to examine the application of energy saving technical and procedural approaches to boats and small cutters. The program consisted of three distinct tasks.

Task 1 identified the energy usage on a platform, system, and component level based on operating profiles, hours of operation per year, systems installed, and operator surveys. A Total Yearly Fuel Consumption Value (TYFCV) was calculated for each boat and cutter type to accurately determine which platforms would benefit from the applications and ultimately save the United States Coast Guard (USCG) the most energy. This analysis proved that the 110' WPB, 87' WPB, 47' MLB, 41' UTB, and Rigid Inflatable Boat (RIB) classes accounted for almost 90 percent of the fuel consumed by boats and single cutters and represent the largest [projected] fuel consumers in the boat and small cutter realm.

Task 2 examined technical and procedural approaches that could reduce energy usage and fuel costs aboard the 110' WPB, 87' WPB, 47' MLB, 41' UTB, and RIB classes. Included in the examination was a preliminary Rough Order of Magnitude (ROM) cost-benefit analysis detailing annual fuel savings and a period of payback. Based on the preliminary ROM analysis, stern flaps, advanced tip propellers, four-stroke outboards, waste oil disposal systems, and fuel additives yielded the highest potential savings and therefore were selected for a more comprehensive examination in the final task.

Task 3 selected approaches were subjected to a more detailed cost-benefit analysis, which considered interest rates, sensitivity, and more accurately accounted for development and installation costs. The analysis concluded that implementing four-stroke outboards in place of two-stroke outboards to propel the RIBs would provide a significant and almost immediate fuel savings. Although providing enhanced capabilities, in the form of increased patrol speed and increased maximum speed, integrating stern flaps aboard the 87' WPB will not decrease fuel consumption. The installation of advanced tip propellers on 87' WPBs is not a viable fuel-saving approach because the payback period for the investment is much too long. Finally, the study recommends that the USCG not consider waste oil disposal systems and fuel additives until sufficient, credible research is conducted.

This study evaluated the applicability and potential fuel saving of current technologies on the present USCG boat and small cutter fleet. To reduce fuel costs in future craft, fuel efficiency must be made a primary requirement and considered as a desirable feature to reduce total ownership cost when evaluating proposed designs. The value of engineering dollars spent up-front to reduce fuel consumption should be considered in light of the life-cycle savings that could be gained.

Contents

Figures

Tables

Acronyms

ANB	Aids to Navigation Boat
BUSL	Buoy Boat Stern Loader
CCD	Combatant Craft Department
CLT	Concentrated Loaded Tip
DFI	Direct Fuel Injection
EFI	Electronic Fuel Injection
ELC	Engineering Logistic Center
GSA	Government Services Administration
MLB	Motor Life Boat
NAVFAC	Naval Facilities Engineering Command
NPV	Net Present Value
NSWCCD	Naval Surface Warfare Center, Carderock Division
PC	Patrol Coastal
PV	Present Value
RIB	Rigid Inflatable Boat
ROM	Rough Order of Magnitude
SIR	Savings to Investment Ratio
SOW	Statement of Work
TAN	Trailered Aids to Navigation Boat
TVF	Tip Vortex Free
TYFCV	Total Yearly Fuel Consumption Value
USCG	United States Coast Guard
UTB	Utility Boat
UTL	Utility Boat Large
WLIC	Inland Construction Tender
WLR	River Buoy Tender
WPB	Patrol Boat
WYTL	Yard Tug Large

Introduction

The United States Coast Guard is required by law to reduce its overall energy consumption at every organizational level including the platform level. Commandant Instruction 4100.2D outlines the energy management policy regarding boat, cutter and aircraft operations, and emphasizes the use of proven engineering retrofits to reduce energy consumption. The United States Coast Guard Research and Development Center tasked the Naval Surface Warfare Center, Carderock Division, Detachment Norfolk, Combatant Craft Department (CCD) to examine the application of energy saving technical and procedural approaches to boats and small cutters.

The study consists of three tasks. The first task required the collection and tabulation of current boat and small cutter fuel usage data to accurately determine which platforms would benefit from the applications and ultimately save the Coast Guard the most energy. The energy consumption examination was carried out and reported in Progress Report 1 (Pogorzelski, 1999).

The second task examined technical and procedural approaches that could reduce energy usage and fuel costs aboard United States Coast Guard boats and small cutters. Included in the examination was a Rough Order of Magnitude (ROM) cost-benefit analysis detailing annual fuel savings and period of payback. Based on the ROM analysis, five approaches were selected for more comprehensive examination in task three.

In the third task, the selected approaches are subjected to a more detailed cost-benefit analysis using NAVFAC Report No. P-442, Economic Analysis Handbook, by Richard S. Brown, et al. Recommendations are made to the Coast Guard listing the approaches CCD considers to offer the largest energy saving, and therefore, they should be considered for possible implementation.

Task 1

Review of Task 1

The primary goal of Task 1 was to calculate the Total Yearly Fuel Consumption Value (TYFCV) for each Coast Guard vessel class. The TYFCV represented the actual number of gallons of fuel burned during a year of operation by a given class. The TYFCV was developed from engine/ generator performance specifications, operational profiles, and hours underway for each class. Additionally, CCD surveyed cutter and boat operators to obtain more realistic operational and fuel consumption information. The surveyed information along with information obtained from Coast Guard publications increased the accuracy of the TYFCV computation.

Task 1 Results

The TYFCV was determined for each USCG small cutter and boat class. Table 1 ranks the vessels by class consumption and by individual vessel consumption. The rankings include projected values for the 47’ MLB, 49’ BUSL, and 87’ WPB based on anticipated builds. As expected, the patrol boats consume the most fuel from both class and individual standpoints.

Table 1. Fuel Consumption Rankings

	TYFCV (gallons)	Ranking by Class Consumption	Number of Cutters/Boats	Average Fuel Consumption per Vessel per Year (gallons)	Ranking by Vessel Consumption
RIBs	906,033	6	379	2,390	15
21' TAN	49,506	15	76	196	18
24' UTL	86,565	12	19	4,556	12
25' UTL	60,170	14	25	2,407	14
41' UTB	1,021,265	5	201	5,081	11
44' MLB[1]	484,921	8	74	6,553	10
46 BUSL[1]	37,510	17	19	1,974	16
47' MLB[2]	1,689,755	4	117	14,442	9
49' BUSL[2]	21,812	18	26	839	17
55' ANB	304,193	10	21	14,485	8
64' ANB	75,264	13	3	25,088	6
65' WYTL	48,686	16	11	4,426	13
65' WLR	324,133	9	6	54,022	4
75' WLIC	153,820	11	9	17,091	7
75' WLR	633,457	7	12	52,788	5
82' WPB[1]	4,171,451	2	36	115,874	2
87' WPB[2,]	4,014,675	3	50	80,294	3
110' WPB	15,923,726	1	49	324,974	1
Total Current[1]	24,280,700	-	940		-
Total Projected[2]	25,313,060	-	1,004		-
[1] Boats listed with a superscript 1 included in Total Current. [2] Boats listed with a superscript 2 included in Total Projected.					

Four vessel classes, 110' WPB, 82' WPB, 41' UTB, and RIBs accounted for almost 90 percent of the fuel consumed. Currently, one 82' WPB is decommissioned every month and replaced with one 87' WPB. Judging from the 87' WPB Class size and the 82' WPBs fuel consumption, the 87' WPB Class will eventually impact the Coast Guard's yearly fuel consumption.

Additionally, as the 47' MLBs continue to replace the aging 44' MLBs, the data suggests that the 47' MLB Class will become a large fuel consumer. Therefore, the 47' MLB Class should be examined for fuel saving technologies. As the largest [projected] fuel consumers in the boat and small cutter realm, the 110' WPB, 87' WPB, 47' MLB, 41' UTB, and RIB Classes were selected as the evaluation platforms for retrofitting the technical and procedural approaches.

Task 2

Review of Task 2

The goal of Task 2 was to compile and evaluate a list of technical and procedural approaches for reducing energy usage and cost. Each technical and procedural change was assessed for its applicability to the 110' WPB, 87' WPB, 47' MLB, 41' UTB, and RIB classes. Each approach was examined based on technical applicability and potential fuel savings. A ROM cost-benefit analysis detailing annual fuel savings and a period of payback was performed for those technical and procedural changes that were technically applicable and likely to reduce energy consumption. Finally, CCD was tasked to generate a matrix for each class detailing which technologies are technically viable and offer a cost benefit.

Fuel Saving Technology Matrix

A list of technical and procedural approaches was compiled from industry research and from the "Suggested List of Fuel Saving Technologies," supplied by the USCG (Anon., 1999). Additional approaches resulted from surveys conducted of crews from the five classes chosen as evaluation platforms. An effort was made to restrict approaches to those with a high degree of technical development. This was done to avoid consideration of approaches that would require exorbitant research and development expenses.

As required by the Statement of Work (SOW), a matrix was created to tabulate each approach and its technical applicability/feasibility and potential cost benefit for each of the five classes. The matrix, shown in Tables 2a and 2b, allows comparisons of approaches within a class and between classes.

Each approach was considered for its technical applicability/feasibility to a given boat or small cutter class. If an approach was both technically applicable and feasible to the class, it was designated "OK" in the matrix. Those approaches found not to be technically applicable or technically feasible were designated "NG" (No Good) in the matrix.

Once an approach was found technically applicable and feasible, a ROM cost-benefit analysis was performed to estimate the period of payback and annual fuel savings as a result of applying the approach to the class. Those approaches providing cost benefits were designated "OK" and those determined to provide no cost benefit were designated "NG."

Numerous reports, technical drawings, and handbooks were reviewed to determine technical applicability and possible cost benefit. Interviews and ship checks were also conducted to aid in the analysis. A list of the more relevant resources is listed in the Bibliography.

Pages 4 and 5, Fuel Saving Technology Matrix (Tables 2a and 2b) are located in a separate file.

ROM Cost-benefit Analysis

The ROM cost-benefit analysis was undertaken to provide an estimated annual fuel savings and project a period of payback. The method chosen to perform the analysis was based on a paper authored by Reyling, Cleary, and Hecker (Reyling, 1999). Each approach represents an estimated reduction in required power, and consequently a fuel savings. It is assumed that the overall resistance reduction equates to reduced fuel consumption and not an increase in operational speeds. Decreasing the required power to maintain current operational profiles result in a decrease in fuel consumption.

Based on the Task 1 fuel consumption results, each class's operational profile and characteristics, and each approach's power reduction, an annual fuel saving was calculated. The annual fuel saving, combined with acquisition/installation costs and engineering/design costs, produced a period of payback. The period of payback was defined as the amount of time necessary to recoup the acquisition/installation and engineering/design costs.

Other assumptions were made in order to estimate the cost benefit of each approach. It was assumed that all of the installation, modification, and retrofit work would be performed during normal overhaul/dry dock periods. Additionally, it was assumed that the approaches would not severely impact the current infrastructure. Those approaches presenting an obvious and significant logistical modification were discarded. Furthermore, savings from extended maintenance and overhaul periods were not considered in this study. Finally, due to fluctuations in fuel costs, it was decided that an arbitrary $1.00 per gallon would be used throughout the ROM study.

Task 2 Results

Based on technical applicability/feasibility, the approaches listed in Table 3 were subjected to the ROM cost-benefit analysis. A more detailed description of the thirteen approaches may be found in Progress Report 2 (Pogorzelski, 2000).

Table 3. Approaches Subjected to ROM Cost-benefit Analysis

Approach	
Fuel Storage	Advanced Engine Technologies
Stern Flaps	Advanced Tip Propellers
Tactics	Rationalized Total Cost Accounting
Waste Oil Disposal	Fuel Additives/Combustion Modifiers
Hull Treatments	Propeller Maintenance/Inspection
Rudder Roll Stabilization	In-Situ Propeller Cleaning/Polishing
Combined Outboard Turning Screws-Fin Between Shafts	

The ROM cost-benefit analysis enabled CCD and Coast Guard representatives to determine which approaches should be pursued in greater detail during Task 3. A meeting was held with

USCG Engineering and Logistic Center (ELC) personnel and USCG Research and Development personnel to select approaches for a more detailed analysis. The meeting participants concluded that the five approaches shown below in Table 4 deserve a more detailed cost analysis.

Table 4. Approaches Selected for Detailed Analysis

Approach	Applicable Craft		Estimated Annual Savings ($)		Estimated Period of Payback (yrs)	
Stern Flap	87’ WPB		206,088		1.3	
Advanced Tip Propellers	87’ WPB		321,174		9.4	
Advanced Engine Technologies (Outboards)	RIBs		407,614		6.0	
Waste Oil Disposal	41’ UTB	47’ MLB	51,054	19,618	19.0	8.8
	87’ WPB	110’ WPB	160,585	812,420	4.7	1.2
Fuel Additives/Combustion Modifiers	RIBs	41’ UTB	54,348	51,064	0.4	0.4
	47’ MLB	87’ WPB	24,551	200,735	0.4	1.3
	-	110’ WPB	-	796,186	-	0.4

Task 3

Economic Analysis Introduction

The cost/benefit analysis is summarized as a series of functions to facilitate an examination of the monetary impact for each of the various fuel-saving approaches selected at the end of Task 2. The functions, described below, follow the guidance of the Economic Analysis Handbook (NAVFAC P-442).

The methodology of the analysis is to calculate yearly savings/cost per vessel and then based on the number of vessels, the yearly class savings. Each particular fuel savings approach is focused on a certain class or classes of vessels in the USCG. Each approach follows the economic analysis process outlined below.

Fuel Saving Benefits

The Total Yearly Fuel Consumption Value (TYFCV), as determined in Task 1, is divided by the number of class vessels to determine the Total Yearly Fuel Consumption Value per Vessel. Using an estimated fuel price, a Yearly Fuel Savings for the class is determined by multiplying the Total Yearly Fuel Consumption Value per Vessel by the number of vessels in the class. For each particular fuel saving approach, this monetary amount is the total savings due to implementing the approach on the respective class.

Investment Costs

The cost to acquire and install the approach aboard each vessel in the class is titled the Acquisition/Install Cost per Vessel. The cost is based on detailed estimates from engineers familiar with the approach’s implementation. The “per vessel” amount is multiplied by the number of vessels to obtain the Acquisition/Install Cost for the Class value.

The Engineering and Design Cost for the Class is based on detailed estimates from engineers familiar with the approach's design. This particular cost is defined as the total engineering and design funding required to test and prepare the approach for implementation. Because each vessel in the class is similar, the Engineering and Design Cost for the Class is only necessary once.

The summation of the Acquisition/Install Cost for the Class and the Engineering/Design Cost for the Class define the Investment Cost for the class. For each particular fuel saving approach, this monetary amount is the total cost for implementation.

Assumptions/Sensitivity

The assumed cost of fuel is $1.00 per gallon. This is a somewhat arbitrary value but represents the lowest likely fuel price in the near future. This simplifies the presentation and interpretation of the data. Savings to Investment Ratio (SIR) will increase and payback period will decrease with a fuel price greater than $1.00/gallon. Therefore, the $1.00 per gallon price represents the worst case the USCG is likely to experience.

An interest rate of four percent is selected to analyze each approach. The four percent interest rate is based on a "real rate of return," or the decreasing purchasing power of money due to inflation. Thus, the chosen interest rate of four percent is due to unknown future general inflation rates. An increased interest rate will increase the payback period and decrease the SIR.

Acquisition/Installation and Engineering/Design Costs were based on program costs compiled from similar concepts, and where possible, from discussions with engineers familiar with the topic. However, uncertainty in the extent of necessary research and development could also influence the payback period. Additionally, shipyard labor and machinery costs vary depending on the company and therefore could affect the results.

The Project Life duration was based on the expected life of the new components. In other words, the technology had to be able to pay for itself before it needed to be replaced. This assures that the analysis is not overly optimistic and allows for the fact that the initial technology may be superceded by future advancements. In some cases, the project life may appear short compared to the expected life of the hardware. Again, this allows for the possibility that the initial technology will become obsolete.

Finally, the USCG-supplied operational profiles have the ability to severely impact the results. Variations in operational procedures could negate or improve the potential benefit of implementing each approach.

SIR Calculation

The calculation of Savings to Investment Ratio is based on methodology outlined in Section 3.7.1 of the Economic Analysis Handbook (NAVFAC P-442). Before the SIR for each approach may be calculated, an interest rate and project life must be assumed. The Discount Factor, which relates future costs to present values, is derived from Appendix C, Table B, of the Economic Analysis Handbook (NAVFAC P-442), using an assumed interest rate and project life. The Net Present Value (NPV) for the project savings and project investment is then determined based on the Discount Factor and project life. The savings NPV is the present value of the savings resulting from the discounting of future yearly savings. The investment NPV is the present value of the initial investment for the project less the present value of any terminal value. Finally, the SIR is established by dividing the savings NPV by the investment NPV. By definition, a SIR must be greater than one for a proposed project to be cost effective.

Discounted Payback Period Calculation

The calculation of the Discounted Payback Period is based on methodology outlined in Section 3.7.2 of the Economic Analysis Handbook (NAVFAC P-442). The Discounted Payback Period is the length of time it takes the savings NPV to equal the investment NPV. One method to determine the Discounted Payback Period is as follows. An interest rate and a SIR equal to one are assumed as parameters for this calculation. Next, the monetary value for Yearly Fuel Savings per Class is redefined as the Present Value (PV) of Savings. The Net Present Value of Investment from the SIR calculation is divided by the Present Value of Savings to obtain the discount factor. This factor is translated to a Discounted Payback Period; defined as the length of time a project needs to amortize itself.

Cost Sensitivity Analysis

Conducting a sensitivity analysis allows an evaluation of the alternative if assumed parameters change while retaining a single baseline reference. In this particular case, the baseline reference is the interest rate for the fuel saving alternative. The analysis begins by altering the Acquisition/ Install Cost per Vessel for a range of monetary values in the region of the original estimate. Tables will show the entire range of cost estimates and corresponding cost investments. Next, the cost investment range is referenced for five cases involving different project lives of various duration. The sensitivity of the analysis to the assumed project life is of interest because the project life is very subjective and open to some debate. For each case, a SIR value is generated for the range of Cost Investment values. Tables are provided which show all the cases with the corresponding SIR values. Figures are used to graphically depict all the cases and their relationship with SIR values in two interpretations: (1) Net Present Value of Investment, and (2) Acquisition/Install Cost per Vessel. The bold line in each figure signifies a SIR value of one. Therefore, if a node is below this line, it represents an Acquisition/Install Cost per Vessel that is not cost effective with the assumed interest rate and the corresponding project life. Nodes above this line are considered cost effective and represent viable fuel saving approaches.

Stern Flaps for 87' WPB

Background

During the last decade, NSWCCD has been developing stern flaps to reduce powering requirements and improve propeller performance on US Navy high-speed displacement craft. Installations and full-scale testing on DD 963, FFG 7, and PC Class ships have proven the value of this technology. Recently, NSWCCD has performed work for the USCG Engineering Logistics Center investigating a stern flap configuration for the 110' WPB. The USCG is currently in the process of installing this stern flap on a 110' WPB for full-scale testing.

Although the 87' WPB was designed and built with an integrated stern wedge, additional benefits are possible with the implementation of a stern flap. As was the case with the 170' PC design, significant powering reductions can be obtained when a stern wedge and flap are employed together.

Fuel Saving Benefits

This analysis focuses on the cost effectiveness of installing a stern flap on an 87' WPB. Although the stern sections of the 87' WPB and the 110' WPB are different, similar benefits are possible. Based on the 110' WPB model testing, a reduction in the 87' WPBs-required power is projected to be 3.7 percent at patrol speed and 5.8 percent at the current maximum speed. These projections would normally be presented as potential savings for the 87' WPB based on an operational profile of 85 percent and 15 percent operation at patrol and maximum speeds, respectively. However, the patrol speed is the best economic speed for the 87' WPB, about 10 knots. A stern flap would increase the best economic speed by a small amount rather than saving fuel. With regard to possible savings at high speed, we must accept that the Coast Guard tends to operate at maximum speed only when response time or speed is critical, and if given the opportunity to go faster, it will. However, this is an operational decision. Therefore, the savings at the present maximum speed will be used to calculate the new Total Yearly Fuel Cost Value per Class. This will give Operations a feeling for the monetary benefits to be obtained from a decision to limit the maximum speed to its current value. This value was then compared to the baseline TYFCV to obtain a Total Yearly Fuel Savings Value per Class of $73,916, calculated based on a fifty 87' WPB patrol boat class.

Investment Costs

The Engineering/Design Cost per Class dominates the total Investment Cost for the stern flap approach. The Engineering/Design Cost per Class, which includes required model testing, is estimated at $115,000 based on the development of the 110' WPB stern flap. An Acquisition/ Install Cost per Vessel of $14,000 is based on USCG ELC supplied data for the installation of the 110' WPB stern flap. This cost includes the stern flap, installation kit, and labor charges. Table 5 shows these investment costs.

Assumptions/Sensitivity

For this analysis, it was assumed that the entire class of fifty 87' WPBs will be in the USCG fleet prior to stern flap installation. As of this publication, twenty-four 87' WPBs have been delivered to the USCG. It is also assumed that an operational profile of 85 percent operation at patrol speed and 15 percent operation at maximum speed is reasonable based on ELC input.

A 20-year project life is chosen for the baseline analysis based primarily on the service life expectancy. It is also assumed that stern flap implementation would occur gradually during regularly scheduled overhaul periods. Therefore, considerable time could elapse between program initiation and full fielding.

A sensitivity analysis is provided to evaluate the feasibility of this technology using different project lives and different cost estimates, while maintaining the same interest rate.

Finally, it is assumed that the stern flaps will not drastically alter mission functions or impede stern ramp operations. NSWCCD engineers do not foresee interference issues and note a similar configuration is currently employed on the transom-extended 170’ PC. These assumptions will need to be validated during model testing and design.

SIRS and Discounted Payback Period Calculations

Based on an interest rate of four percent and a project life of 20 years, the resulting SIR is 1.2 for the total operational profile. Therefore, a stern flap is cost effective based on the above parameters. For the same interest rate, the discounted payback period for the profile is more than fifteen years. Details are given in Table 6.

Cost Sensitivity Analysis

For the cost-sensitivity analysis, the baseline reference is the interest rate of four percent. The analysis begins by altering the Acquisition/Install Cost per Vessel for a range of values between $10,000 and $20,000. This results in a range of Cost Investment for the class between $615,000 and $1,115,000. Table B-1 shows the entire range of Cost Estimates and corresponding Cost Investments for installation of stern flaps. These data represent the total operational profile. Next, this range of cost investments is referenced for five cases involving different project lives of 10, 15, 20, 25, and 30 years. The SIR calculations are done for the total operational profile and the data is shown in Table B-2. Figure 1 graphically demonstrates all the cases with their relationship to SIR and the Net Present Value of Investment. Figure 2 graphically demonstrates all the cases with their relationship to SIR and the Acquisition/Design Cost per Vessel. In all the figures, the bold line signifies a SIR value of one. Therefore, if a node is below this line, it represents a cost of a stern flap that is not cost effective with the corresponding project life.

All cases studied with project lives of 25 years and above are economically feasible. Therefore, a stern flap is cost effective for the 87’ WPB, provided that operations be restricted to the current maximum speed.

Recommendations

The installation of a stern flap on 87’ WPBs is a viable fuel-saving approach for the USCG. A stern flap has been developed for, and is currently being installed on, a 110’ WPB. Significant fuel savings have been predicted. Analysis suggests that similar results could be achieved for the 87’ WPB. In terms of cost analysis, the payback period for this approach is about fifteen years. However, it is unlikely that operations would decide to restrict the maximum speed of the 87’ WPB to its current value. Therefore, the fuel saving approach of installing stern flaps on the 87’ WPB is not recommended.

Table 5. Savings/Cost Function Tables for Cost/Benefit Analysis of Stern Flaps for 87' WPBs

Maximum Speed

Savings Function	Total Yearly Fuel Consumption Value	Operational TYFCV	Number of Vessels	TYFCV per Vessel	Fuel Efficiency Percentage (%)	Yearly Fuel Savings per Vessel	Yearly Fuel Savings for Class	Fuel Price	Yearly Fuel Savings for Class
Measurement	gallons per year	gallons per year		gallons per vessel		gallons per vessel	gallons for Class	dollars per gallon	dollars for class
	4,014,675	1,274,410	50	25,488	5.8	1,478	73,916	$1.00	$73,916

Cost Function	Acquisition/Install Cost per Vessel	Engineering/Design Cost per Class	Number of Vessels	Cost Investment for Class
Measurement	dollars per vessel	dollars per Class		dollars for Class
	$14,000	$115,000	50	$815,000

Table 6. SIR and Discounted Payback Period Tables for Cost/Benefit of Stern Flaps for 87' WPBs

Calculating Savings to Investment Ratio (SIR):
Interest Rate = 4%
Project Life = 20 Years

Discount Factor[1]	Net Present Value (NPV) of Savings	Net Present Value (NPV) of Investment	Savings to Investment Ratio (SIR)[2]
13.5903	$1,004,538	$815,000	1.2

Calculating Discounted Payback Period:
SIR = 1
Interest Rate = 4%

SIR	Present Value (PV) of Savings	Net Present Value (NPV) of Investment	Discount Factor[3]	Payback Period[4] (Years)
1.0	$73,916	$815,000	11.0	15+

notes:

[1] = derived from the Economic Analysis Handbook NAVFAC P-442 (Appendix C, Table B) using given interest rate and project life

[2] = SIR must be greater than 1 for proposed project to be cost effective

[3] = cumulative uniform series discount factor required to make the SIR = 1

[4] = derived from the Economic Analysis Handbook NAVFAC P-442 (Appendix C, Table B) using given interest rate and calculated payback period

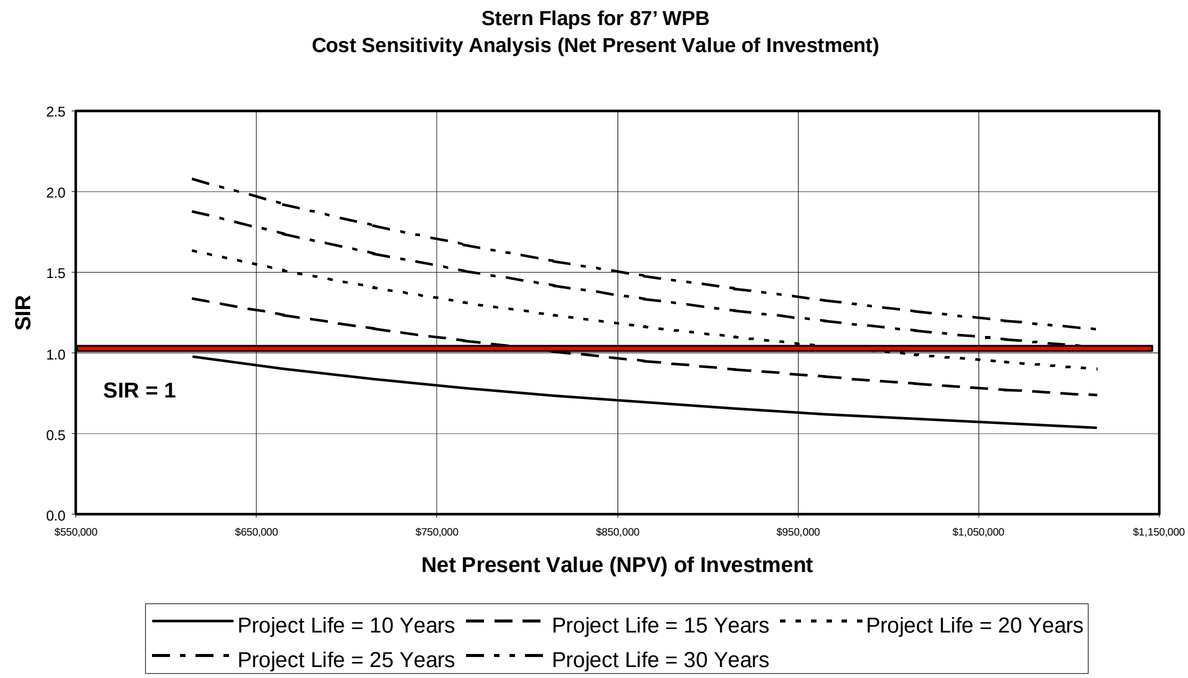

Figure 1. Stern Flaps for 87' WPB Cost Sensitivity Analysis (Net Present Value of Investment)

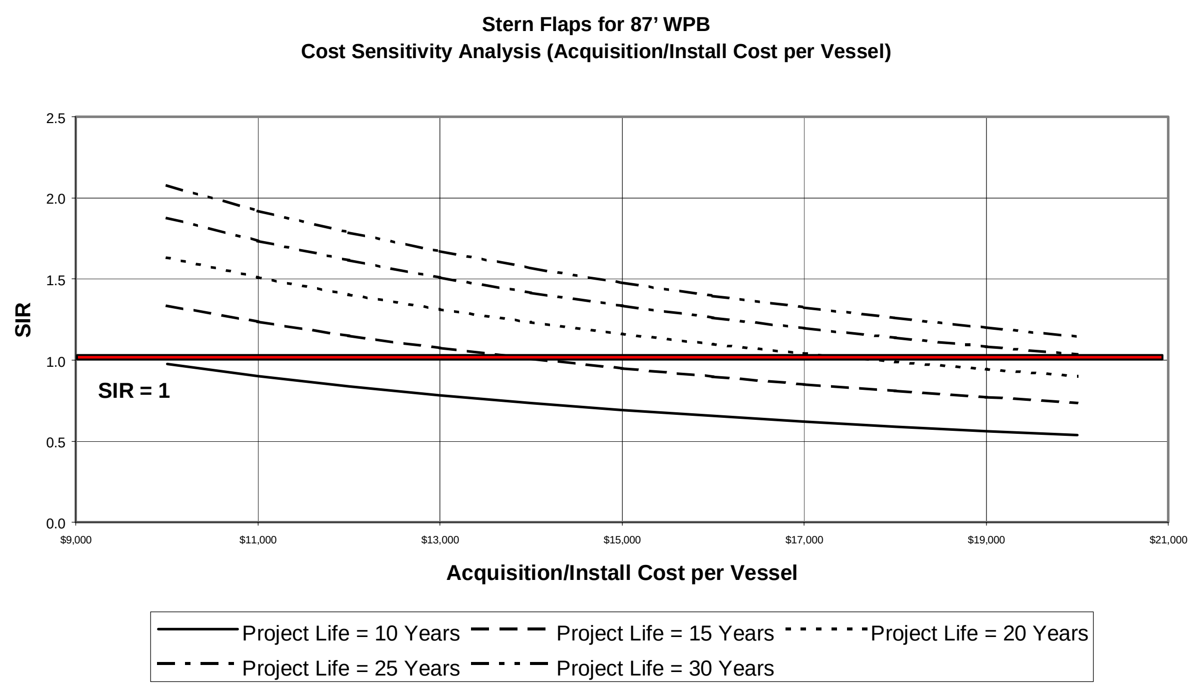

Figure 2. Stern Flaps for 87' WPB Cost Sensitivity Analysis (Acquisition/Install Cost per Vessel)

Advanced Tip Propellers for 87' WPB

Background

Many modern high-speed propellers exhibit tip vortex cavitation. The local pressure in the tip vortex core drops to the vapor pressure of the liquid, the liquid boils, and cavitation occurs. The amount of tip vortex cavitation is directly proportional to the strength of the tip vortices. The efficiency of high-speed propellers is often limited by the onset of cavitation beginning with tip vortex cavitation.

The main focus of advanced tip propellers is to control tip vortex cavitation. Controlling this cavitation allows the use of design features that result in an increase in the efficiency of the propeller. Advanced tip propellers, such as Concentrated Loaded Tip (CLT), Tip Vortex Free (TVF), and Kappel propellers, are designed to heavily load the blade tips while still retaining acceptable cavitation performance (Cusanelli, 1996). Also recognized as "tip loaded propellers," they are characterized by the large degree of rake and skew in the tip region. Their installation on an 87' WPB would result in a more fuel-efficient craft due to lower power requirements at patrolling speed. If designed properly, the installation of advanced tip propellers on the 87' WPB should not require additional modifications.

It is important to note that advanced tip propellers have not proven to be more efficient than conventional propellers for all situations/cases. Tip-loaded propellers are less efficient at light loads than typical propellers due to viscous and induced losses. For the case of CLT propellers at light loads, the increased wetted surface of the blades near the tips significantly enhances viscous losses [Mishkevich, 1994]. This should not be a factor for the propeller loading typical of 87' WPB operations. Figure 3 shows a typical CLT propeller.

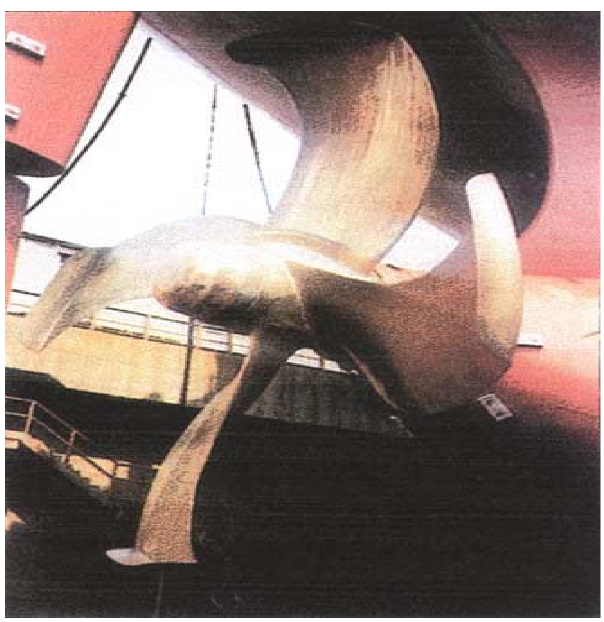

Figure 3. Typical CLT Propeller

Figure 4 shows the propeller curve plots for the following three propellers:

1. USCG 110’ WPB Propeller 5128 (current propeller)
2. USCG 110’ WPB Propeller Design #4
3. USCG 87’ WPB Propeller BSI Propulsion Calculations

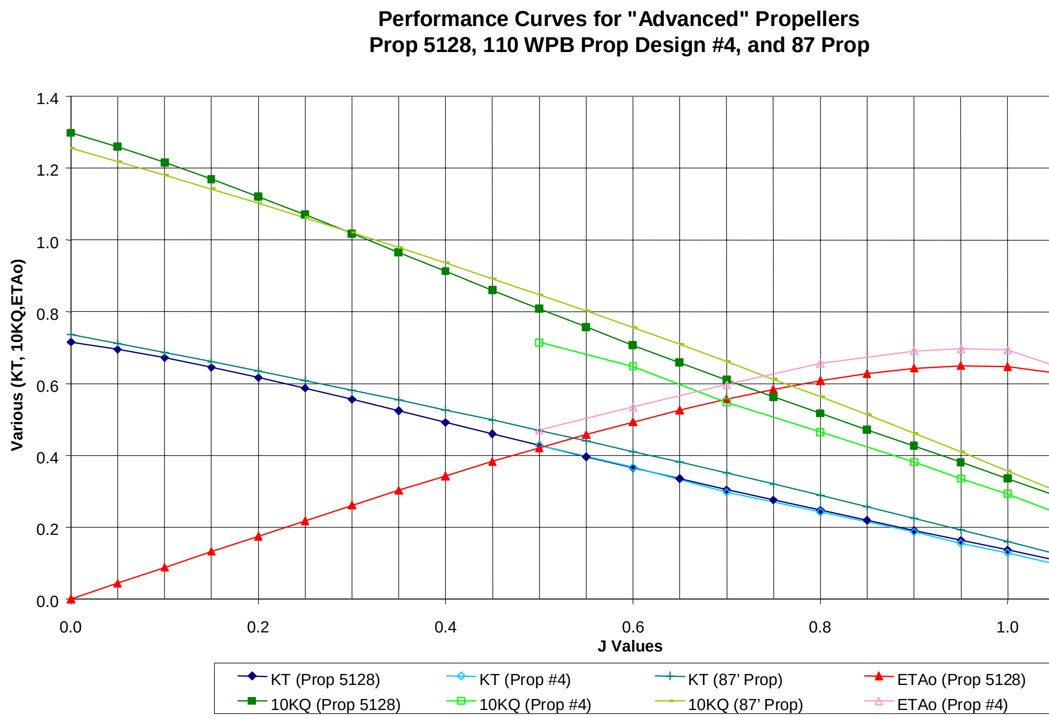

Figure 4. Propeller Curve Plots for Three Propellers

Fuel Saving Benefits

Fuel savings from the use of advanced tip propellers could result from operating the craft at the same speed as with the original propellers but at less required power. However, as with the stern flap, the savings at patrol speed, which accounts for 85 percent of the operational time, cannot be realized because the patrol speed is the best economic speed. The potential patrol speed savings is translated into a faster patrol speed. Only at maximum speed, which accounts for 15 percent of the operational hours, is a fuel saving obtainable. NSWCCD engineers responsible for numerous advanced tip propeller designs estimate a fuel saving of 6-7 percent over the current 87’ WPB propeller. For this particular approach, the Yearly Fuel Savings for the class is the total savings realized from outfitting advanced tip propellers on the entire 87’ WPB class. The analysis, shown in Table 8 and based on the USCG supplied operational profile, concludes that implementing advanced tip propellers throughout the class will not save USCG money. Only after more than fifty years will the advanced tip propeller approach become cost effective.

Investment Costs

The acquisition price of advanced tip propellers dominates their investment cost. Also included in the investment cost are the design/engineering costs and all associated testing.

The Acquisition/Install Cost per Vessel, based on NSWCCD advanced tip propeller projects, is estimated at $60,000 per propeller pair. However, according to ELC personnel, the original 87' WPB propeller procurement contained fifty pairs and twenty-two spares. To accurately account for the spares, the cost of twenty-two additional propellers is spread equally over each vessel's acquisition/install cost.

The Engineering/Design Cost per Class, estimated at $60,000, is also based on NSWCCD's experience. The Investment Cost is a summation of the Acquisition/Install Cost and Engineering/Design Cost for the class and represents the total cost of outfitting advanced tip propellers on 87' WPB class. The entire method is shown below in Table 7.

Assumptions/Sensitivity

For this analysis, it is assumed that fifty 87' WPBs will be in the USCG fleet. As of this publication, twenty-four 87' WPBs have been delivered to the USCG. Additionally, it is assumed that 122 advanced tip propellers will be manufactured to replace the current stock of 87' WPB propellers.

Additional assumptions were made regarding the Engineering/Design Cost per Class. The 110' WPB advanced tip propeller was based on resistance model testing performed as part of the 110' WPB stern flap investigation and extensive design work on the 170' PC propeller. Because of this and budgetary limits, the 110' WPB propeller was designed and submitted without detailed propeller testing. The $60,000 Engineering/Design Cost per Class was supplied by the NSWCCD engineer who led the 110' WPB advanced tip propeller effort. The engineer concluded that a similar effort could be employed for the 87' WPB with a minimal level of risk. However, should the USCG desire to reduce the design risk, the following costs would have to be included:

Propeller Powering Model	=	$50,000
Propeller Open Water Tests	=	$25,000
Propulsion Tests	=	$100,000
Propeller Cavitation Model	=	$40,000
Cavitation Test (Water Tunnel)	=	$80,000
Total		**$295,000**

The analysis also assumes that adequate resistance data are available prior to the propeller design. If adequate resistance data are not available, an additional $115,000 is estimated to obtain it. The 110' WPB effort reduced cost by basing the advanced tip propeller design on data obtained during the stern flap investigation.

A twenty-year project life is selected for this fuel-saving approach. It could be argued that the new propellers should last the life of the craft. Using a twenty-year project life allows for casualty losses and the possibility that technological advances would lead to early replacement of these propellers. A sensitivity analysis is provided to evaluate the feasibility of this technology using different project lives and different cost estimates, while maintaining the same interest rate.

SIRS and Discounted Payback Period Calculations

Based on an interest rate of 4 percent and a project life of 20 years, the resulting SIR is 0.3. Therefore, this project is not cost effective for the above parameters. For the same interest rate, the discounted payback period is longer than fifty years. Details are given in Table 8.

Cost Sensitivity Analysis

For the cost sensitivity analysis, the baseline reference is the four percent interest rate. The analysis begins by altering the Acquisition/Install Cost per Vessel for a range of values between $50,000 and $90,000. This results in a range of Cost Investment for the class between $2,560,000 and $4,560,000. Table C2 in the Appendix shows the entire range of cost estimates and corresponding cost investment. Next, this range of cost investments is referenced for five cases involving different project lives of ten, fifteen, twenty, twenty-five, and thirty years. Table C3 shows all the cases with the corresponding SIR values. Figure 5 graphically demonstrates all the cases with their relationship to SIR and the Net Present Value of Investment. Figure 6 graphically demonstrates all the cases with their relationship to SIR and the Acquisition/Design Cost per vessel. In both Figures 5 and 6, the bold line signifies a SIR value of one. Therefore, if a node is below this line, it represents a cost of the advanced tip propeller that is not cost effective with the corresponding project life. **For project lives of ten through thirty years, all cases are not feasible with any cost of an advanced tip propeller.**

Recommendations

The installation of advanced tip propellers on the USCG 87’ WPB is not a viable fuel-saving approach for the USCG. Analysis suggests that fuel savings could not be obtained due to the fact that the patrol speed is the best economic speed, and percentage of time operating at maximum speed. The payback period for this approach is more than fifty years. Therefore, installation of advanced tip propellers on the 87’ WPB is not recommended based on cost effectiveness and payback period.

Table 7. Savings/Cost Function Tables for Cost/Benefit Analysis of Advanced Propellers for 87' WPBs

CLT / TVF / Kappel Propellers

Savings Function	Total Yearly Fuel Consumption Value	Operational TYFCV	Number of Vessels	TYCFV per Vessel	Fuel Efficiency Percentage (%)	Yearly Fuel Savings per Vessel	Yearly Fuel Savings for Class	Fuel Price	Yearly Fuel Savings for Class
Measurement	gallons per year	gallons per year		gallons per vessel		gallons per vessel	gallons for Class	dollars per gallon	dollars for class
	4,014,675	1,274,410	50	25,488	7	1,784	89,209	$1.00	$89,209

Cost Function	Acquisition/Install Cost per Vessel	Engineering/Design Cost per Class	Number of Vessels	Cost Investment for Class
Measurement	dollars per vessel	dollars per Class		dollars for Class
	$73,200	$60,000	50	$3,720,000

Table 8. SIR and Discounted Payback Period Tables for Cost/Benefit Advanced Propellers for 87' WPBs

Calculating Savings to Investment Ratio (SIR):
Interest Rate = 4%
Project Life = 20 Years

Discount Factor[1]	Net Present Value (NPV) of Savings	Net Present Value (NPV) of Investment	Savings to Investment Ratio (SIR)[2]
13.5903	$1,212,373	$3,720,000	0.3

Calculating Discounted Payback Period
SIR = 1
Interest Rate = 4%

SIR	Present Value (PV) of Savings	Net Present Value (NPV) of Investment	Discount Factor[3]	Payback Period[4] (Years)
1.0	$89,209	$3,720,000	41.7	50+

notes:

[1] = derived from the Economic Analysis Handbook NAVFAC P-442 (Appendix C, Table B) using given interest rate and project life

[2] = SIR must be greater than 1 for proposed project to be cost effective

[3] = cumulative uniform series discount factor required to make the SIR = 1

[4] = derived from the Economic Analysis Handbook NAVFAC P-442 (Appendix C, Table B) using given interest rate and calculated payback period

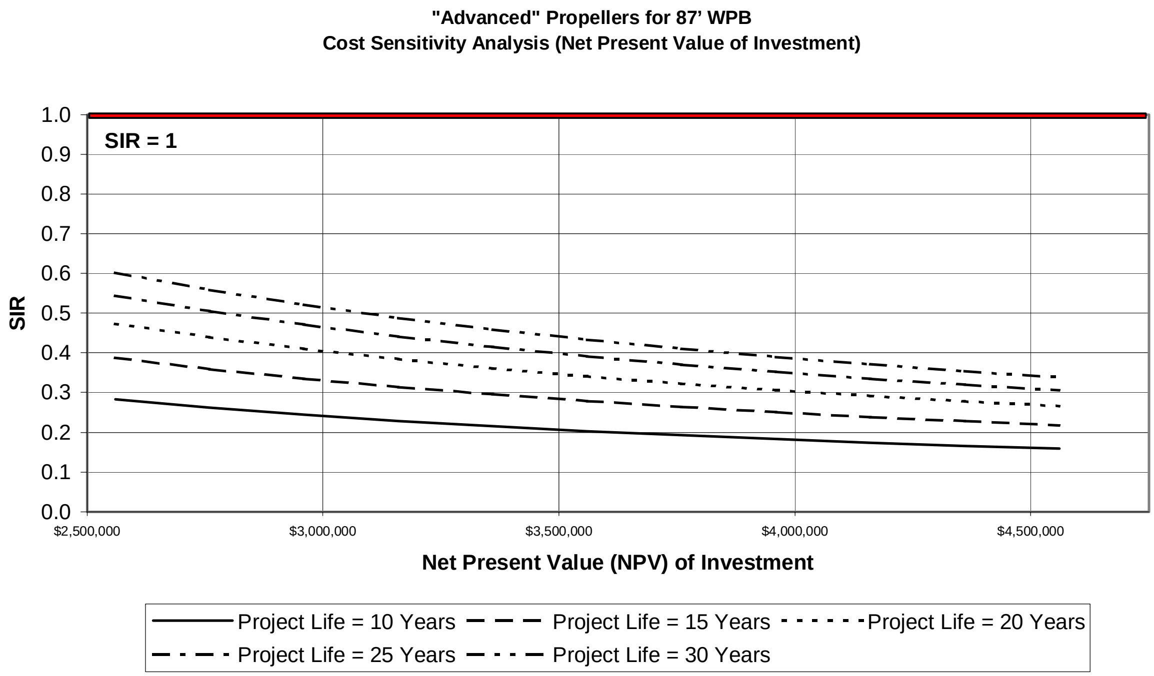

Figure 5. Advanced Propellers for 87' WPB Cost Sensitivity Analysis (Net Present Value of Investment)

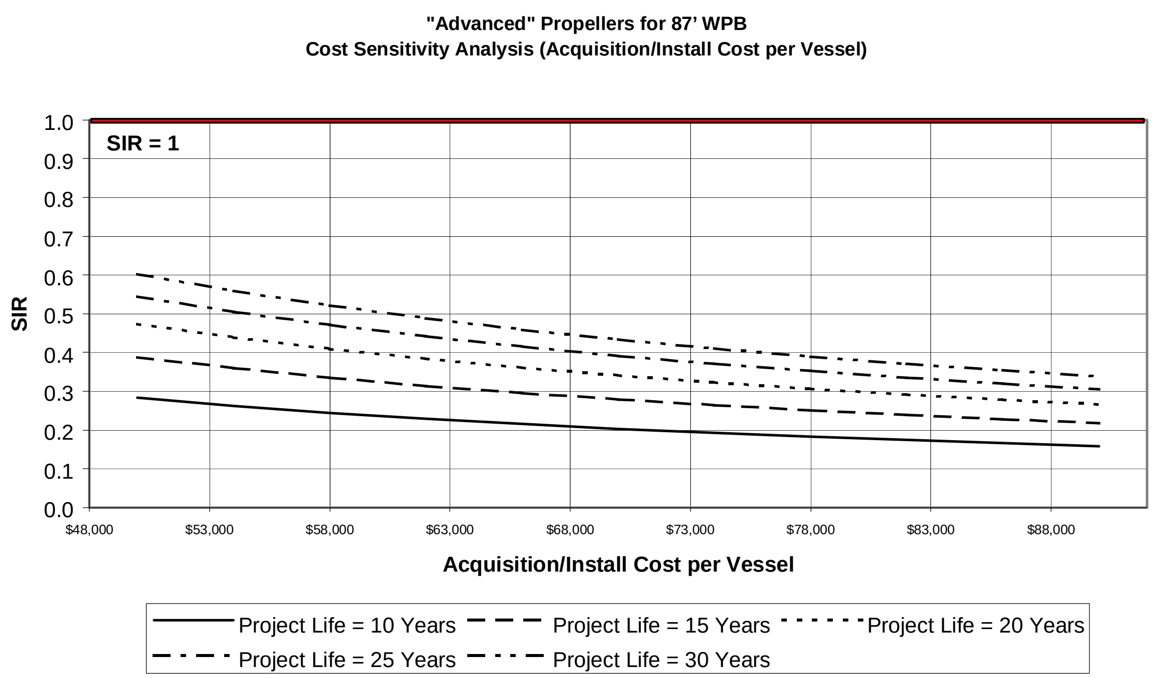

Figure 6. Advanced Tip Propellers for 87' WPB Cost Sensitivity Analysis (Acquisition/Install Cost Per Vessel)

Advanced Engine Technologies (Four-Stroke Outboards) for RIBs

Background

A number of outboard manufacturers have added, or are in the process of adding, four-stroke models to their current model lineup in anticipation of more stringent environmental regulations. Currently, available four-stroke outboards range from 40 hp to 130 hp with dry weights from 211 lb (95.5 kg) to 505 lb (229 kg), respectively. They are heavier than a two-stroke engine of comparable power due to the higher internal loads on a four-stroke engine. As of this publication, the most powerful four-stroke outboard engine available in the United States is made by Honda.

Four-stroke outboard engines are quickly becoming a leading alternative for meeting present and pending environmental restrictions. Table 9 is a current list of manufacturers with four-stroke outboard engines in their product line. Also listed in the table are the horsepower, the dry weight of each outboard engine, and sample General Services Administration (GSA) prices from Tidewater dealers. Many meet or exceed the Environmental Protection Agency's (EPA) requirements for 2006.

In terms of environmental and economic benefits, four-stroke outboard engines have a number of favorable characteristics. The use of the four strokes allows the engine to produce the same horsepower as two strokes with considerably less fuel. A survey of current four-stroke outboard engine manufacturers reveals claims of 30-35 percent better fuel economy than conventional carbureted or Electronic Fuel Injection (EFI) two-stroke outboard engines. The combustion efficiency of the four-stroke outboard engines results in lower emissions than similarly powered two-stroke outboard engines.

Unlike two-stroke outboard engines, four-stroke outboard engines do not require mixing oil with the fuel for internal lubrication. The results are outboard engines with considerably less exhaust smoke at all speeds including idle. Furthermore, four-stroke outboard engines do not exhibit the characteristic vibration so common with two-stroke outboard engines while operating near idle. Finally, four-stroke engines permit extended idling without the threat of clogged valves typical of two-stroke engines. Many new outboard engines have advanced engine sensing and warning systems that provide better feedback to the operator on engine condition.

In addition to acquisition cost, reliability remains the dominant issue regarding four-stroke engine budgets. As with most new mechanical devices, early four-stroke outboard engines were subject to numerous reliability and performance problems. Recent USCG station reports document countless problems with early four-stroke engines. Most problems occur after 300 hours of operation and include blown powerheads, fuel dilution concerns, and piston seizures. Some stations do not believe that current four-stroke outboard engines are reliable enough to be installed on RIBs assigned to search and rescue missions. They emphasize that outboard engine failure during such a mission would be disastrous.

Another challenge is the added weight of the four-stroke engine technology. For example, a Mercury 90 hp four-stroke outboard engine weighs 386 pounds, while a Mercury 90 hp two-stroke outboard engine weighs only 303 pounds. This 28 percent weight increase may substantially affect the performance of small craft. Throughout the power range, four-stroke outboard engines are on average 25 percent heavier than their two-stroke counterparts.

An additional concern is the lack of four-stroke outboard engines rated above 130 hp (see Table 9). At present, many Coast Guard RIBs are powered by two-stroke engines that have a rated horsepower above 130 hp.

Fuel Saving Benefits

The total number of gallons consumed yearly by each vessel is almost 2400 gallons. The fuel efficiency increase of 30 percent is an average of the researched fuel efficiency claims from Coast Guard station operators. This is a conservative estimate when compared to some manufacturer's claims. For this particular fuel-saving approach, the Yearly Fuel Saving for the class is the total savings obtained from outfitting the entire class of RIBs with four-stroke outboard engines. This savings value totals $271,810. The entire method is shown below in Table 10.

Investment Costs

The $1200 Acquisition/Install Cost per vessel is an average cost difference between four-stroke outboard engines and two-stroke outboard engines with comparable horsepower. Outboard engine prices were averaged based on current GSA contracts.

There is no additional cost for Engineering/Design due to manufacturer's production. The Investment Cost for the Class of vessels is the total cost of outfitting each RIB with a single four-stroke outboard engine. The entire method is shown below in Table 10.

Assumptions/Sensitivity

For this analysis, it is assumed that the 379 RIBs currently employed by the USCG will remain active throughout the project life. It is assumed that the new four-stroke engines will be installed in place of two-stroke engines that require replacement.

A five-year life was used as the baseline for the project life of this fuel-saving approach. This project life was chosen based on USCG station reports documenting life expectancy of outboard engines and conversations with station personnel. Most stations reported a normal usage of 300 hours until failure. A report follows from a USCG station detailing an outboard engine failure at 300 hours.

> STATION ENGINEER INSPECTED MOTOR AND FOUND AN APPROXIMATE HALF INCH HOLE IN THE BLOCK, AND COULD SEE THE CONNECTING ROD END CAP THROUGH THAT HOLE. UNIT ENGINEER CONTACTED LOCAL TECH REP, AND PLANS ARE TO CHANGE OUT THE BLOWN MOTOR WITH STATIONS SPARE. TECH REP ALSO WOULD LIKE TO CONDUCT A "SET UP" TEST WHEN SPARE MOTOR IS INSTALLED. BOTH THE BLOWN ENGINE AND UNIT SPARE ARE CURRENTLY UNDER WARRANTY. WARRANTY EXPIRES MAY 2000. IT HAS APRROX. 300 HRS.

A sensitivity analysis is provided which evaluates the feasibility of this technology using different years for project life and different cost estimates, while maintaining a constant interest rate.

SIRS and Discounted Payback Period Calculation

An interest rate of four percent and a project life of five years result in a SIR value of 2.7. Therefore, this project is cost effective based on the above parameters. For the same interest rate, the discounted payback period is about 1.8 years. Details are given in Table 11.

Cost Sensitivity Analysis

In this particular case, the baseline reference is the four percent interest rate. The analysis begins by altering the Acquisition/Install Cost per Vessel, defined in this case as the monetary difference between four-stroke and two-stroke outboard engines of the same horsepower for a range of values between $500 to $3000. This results in a range of cost investments for the class between $189,500 to $1,137,500. Table D1 in the appendix shows the entire range of cost estimates and corresponding cost investments. Next, the cost investment range is referenced for five cases involving different project lives of one, three, five, eight, and ten years. Appendix Table D2 shows all cases with the corresponding SIR values. Figure 7 graphically demonstrates all the cases with their relationship to SIR and the Net Present Value of Investment. Figure 8 graphically demonstrates all the cases with their relationship to SIR and the Acquisition/Install Cost per vessel. In both figures, the bold line signifies a SIR value of one. Therefore, if a node is below this line, it represents a four-stroke outboard cost that is not cost effective with the corresponding project life. For project lives of five through ten years, all cases are cost effective.

Issues/Shortcomings/Concerns

Some manufacturers are currently marketing direct fuel injected (DFI) two-stroke outboard engines that they claim match the fuel economy demonstrated by comparable four-stroke outboards. Also, two-stroke outboard engines with direct fuel injection are available above 200 horsepower. This horsepower output is not yet available with four-stroke technology. However, this technology is newer than the four-stroke technology currently being used; therefore, it is less proven.

Table 9. Four-stroke outboards comparison

Manufacturer	HP	Weight (lbs)	GSA Prices*
Evinrude	70	342	$7,430
	50	238	$7,250
	40	238	$7,080
Honda	130	505	$10,500
	115	496	$9,600
	90	384	$8,900
	75	384	$8,400
	50	211	$8,000
	40	211	$7,800
Mercury	90	386	$5,441
	75	386	$5,104
	50	224	$4,398
	40	228	$4,094
Suzuki	70	335	$6,800
	60	335	$6,600
	50	238	$6,100
Yamaha	115	398	$10,400
	100	356	$9,600
	80	356	$8,900
	50	233	$7,200
	40	181	$6,500

*Includes full installation of controls and outboard (as of September 2000)

Recommendations

The installation of four-stroke outboard engines on USCG RIBs is a viable option that should be considered as a fuel-saving approach. Furthermore, four-stroke outboard engines should be considered for all other USCG outboard-powered boats as well. As stricter environmental legislation mandates more fuel efficient outboard engines, the USCG must move towards technology that is not only fuel efficient, but also able to perform reliably in their current daily operations. Today's four-stroke outboard engines are lacking in the higher power ranges. Manufacturers are promising higher horsepower units are on the horizon. Likewise, reliability will increase as more four-stroke outboard engines are fielded. The implementation of four-stroke outboard engines will be cost effective and environmentally friendly.

Table 10. Savings/Cost Function Tables for Cost/Benefit Analysis of Four-Stroke Outboards for RIBs

Savings Function	Total Yearly Fuel Consumption Value	Number of Vessels	TYFCV per Vessel	Fuel Efficiency Percentage (%)	Yearly Fuel Savings per Vessel	Yearly Fuel Savings for Class	Fuel Price	Yearly Fuel Savings for Class
Measurement	gallons per year		gallons per vessel		gallons per vessel	gallons for Class	dollars per gallon	dollars for class
	906,033	379	2,391	30	717	271,810	$1.00	$271,810

Cost Function	Acquisition/Install[5] Cost per Vessel	Engineering/Design Cost for Class	Number of Vessels	Cost Investment for Class
Measurement	dollars per vessel	dollars for Class		dollars for Class
	$1,200	$0	379	$454,800

Table 11. SIR and Discounted Payback Period Tables for Cost/Benefit Analysis of Four-Stroke Outboards for RIBs

Calculating Savings to Investment Ratio (SIR):
Interest Rate = 4%
Project Life = 5 Years

Discount Factor[1]	Net Present Value (NPV) of Savings	Net Present Value (NPV) of Investment	Savings to Investment Ratio (SIR)[2]
4.4518	$1,210,043	$454,800	2.7

Calculating Discounted Payback Period
SIR = 1
Interest Rate = 4%

SIR	Present Value (PV) of Savings	Net Present Value (NPV) of Investment	Discount Factor[3]	Payback Period[4] (Years)
1.0	$271,810	$454,800	1.7	1.8

notes:

[1] = derived from the Economic Analysis Handbook NAVFAC P-442 (Appendix C, Table B) using given interest rate and project life.
[2] = SIR must be greater than 1 for proposed project to be cost effective.
[3] = cumulative uniform series discount factor required to make the SIR = 1.
[4] = derived from the Economic Analysis Handbook NAVFAC P-442 (Appendix C, Table B) using given interest rate and calculated payback period.
[5] = derived from cost difference between a four-stroke outboard and a two-stroke outboard with comparable horsepower.

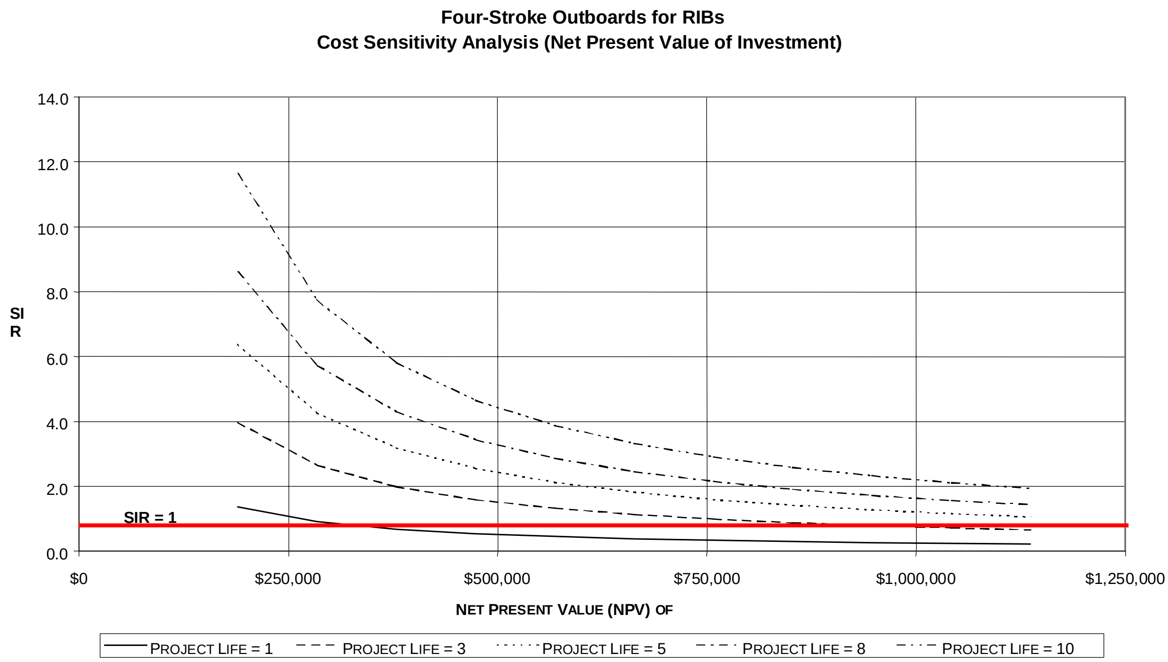

Figure 7. Four-Stroke Outboards for RIBs Cost Sensitivity Analysis (Net Present Value of Investment)

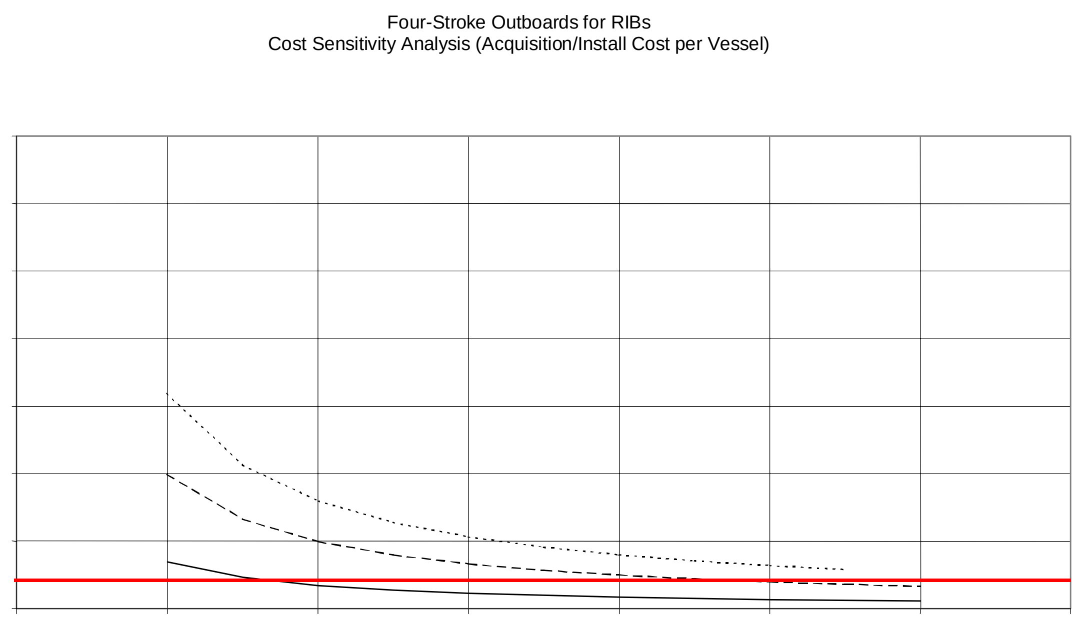

Figure 8. Four-Stroke Outboards for RIBs Cost Sensitivity Analysis (Acquisition/Install Cost per Vessel)

Waste Oil Disposal

Background

The U.S. Army Oil Analysis Program has experimented with blending used oil with conventional fuel for diesel combustion (Brown, 1999). The Cummins Engine Corporation has expanded on the subject and devised an electronic system to transfer a small portion of used lubrication oil to the fuel system for consumption.

The system, termed the CENTINEL Advanced Engine Oil Management System, is installed on existing diesel engines and operates as an integrated part of the engine. The CENTINEL system periodically removes a small amount of used lube oil and transfers it to the fuel oil tank. This is done to blend used oil with fuel oil for incineration during the engine's regular combustion process. The system's components monitor the transfer process to assure the optimum amount of blended oil (typically 1:20) is available based on the engine's duty cycle and load factor. To maintain the correct quantity of lube oil, the system draws new lube oil from a "make-up" reservoir to replace the quantity transferred to the fuel oil tank. The process is illustrated below in Figure 9.

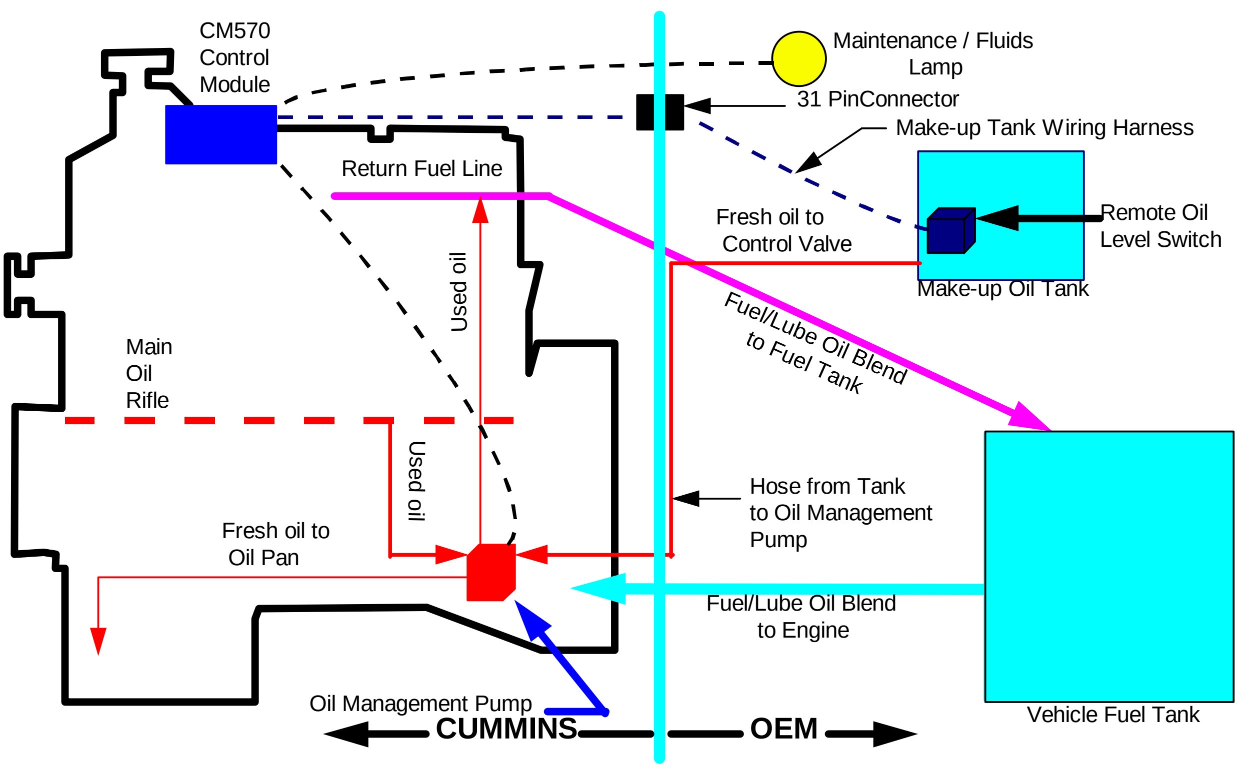

Figure 9. CENTINEL System diagram (from Cummins Engine Co. Inc.)

Cummins Engine Co. Inc., claims the CENTINEL System allows a diesel engine to operate longer and more protected due to the better oil management. Additional claims include decreased maintenance time and money due to increased overhaul intervals. Continuous exchange of oil into the lubrication system ensures oil quality stays stable. Cummins claims this provides excellent protection for the duration of engine operation.

As defined in the Economic Analysis Handbook NAVFAC P-442, CENTINEL can be classified as a self-amortizing project that will pay for itself. Cummins claims that in most applications, CENTINEL will pay for itself in less than two years. The typical installation cost for the CENTINEL system is $8000 per engine.

While increasing the interval between lube oil changes, the system also decreases the quantity of fuel oil burned. Approximately five percent of the fuel oil that would typically be consumed is replaced by used lube oil that would traditionally have to be pumped ashore. The blending minimizes the need for disposal and converts used lube oil into productive energy, thereby reducing overall fuel consumption.

Reliability remains a primary concern with the implementation of the CENTINEL System. Although Cummins provides supporting test data, no independent test results are available that examine the adverse effects (if any) of burning used lube oil.

The decision to not perform an economic analysis on the CENTINEL is based on the lack of independent test data to address reliability concerns. Therefore, it is deemed inappropriate to justify this savings approach without quantitative test results.

Recommendations

The Cummins CENTINEL Advanced Engine Oil Management System is a fuel-saving approach that requires additional research before implementation aboard USCG craft. A complex system that directly influences the mechanical performance and ultimately the projected life of a marine diesel engine should be examined thoroughly by independent testing to evaluate its impact.

Fuel Modifiers

Background

For years, fuel modifiers have promised increases in fuel economy, performance, and engine life. They also have claimed to reduce emissions, engine wear, and downtime. Today, there are more than one hundred different fuel modifiers on the market from as many manufacturers.

A market survey was conducted to acquire the latest information on fuel modifiers. A Request for Information (RFI), shown in Appendix E, was submitted via a Commerce Business Daily (CBD) to allow fuel modifier manufacturers to submit product characteristics and independent test data. Table 12 shows the results from the RFI. The survey was limited to products that are added directly to the fuel rather than attached to the engine. The table shows the product’s name and its respective manufacturer. The designation of the type of product is also shown. The fuel economy claims are based strictly on information supplied by the manufacturer.

Table 12. Fuel Modifiers Survey

Maker	Product Name	Designation	Fuel Economy Claim	Other Economic Claim
Clean Diesel Technology	Platinum Plus DFX	Fuel Additive	improve 5%-7%	increase horsepower
Fitch	Fitch	Fuel Catalyst	improve 5%-12%	reduce down time
Fuel Tek Marine	CAL-5	Fuel Additive	improve 4%-6%	increase horsepower
Hammonds	Select 3 Marine 3	Fuel Additive	n/a[1]	increase filter life
Hammonds	Select 3	Fuel Additive	n/a[1]	increase filter life
ILFC, Inc.	Ten-35	Fuel Additive	improve 15%	reduce maintenance cost
MFC	ALGAE-X	Fuel Catalyst	n/a[1]	preserve stored fuel
Soltron	Soltron	Fuel Additive	improve up to 15%	reduce maintenance cost
Bell Additives	MIX-I-GO (Gasoline)	Fuel Additive	n/a[1]	extend spark plug life
Bell Additives	DEE-ZOL (Diesel)	Fuel Additive	improve 4.3%	increase engine life

1 - signifies no qualitative assessment for fuel economy

Most fuel modifiers claim to "clean" the fuel to ensure more efficient combustion. The method by which the fuel is "cleansed" varies dramatically from product to product. In all cases, the product is mixed with the existing fuel and no other action is needed. The simplicity of these products is a definite benefit.

Fuel modifiers claim a wide range of additional benefits. Each modifier claims to reduce emissions and increase performance. As shown in Table 13, while all claim increased fuel economy, only half of the manufacturers provided a quantitative assessment. Furthermore, no independent test data could be obtained to corroborate any quantitative data. Instead, most manufacturers supplied testimonials that could not be supported or challenged.

The decision to not perform an economic analysis on fuel modifiers is based on the lack of independent test data to support any arguments. Therefore, it was deemed inappropriate to justify this savings alternative without sufficient quantitative test results.

Recommendations

Fuel modifiers are a fuel-saving approach that requires independent testing to support its cost effectiveness. The USCG should be hesitant to select fuel modifiers based on claims and testimonials provided by manufacturers. Without sufficient independent testing to prove (or disprove) these claims and testimonials, fuel modifiers cannot be recommended as a viable fuel-saving approach.

Conclusion

Results Comparison

The fuel-saving approaches with their respective applicable craft are shown in Table 13. The table also summarizes the differences in Payback Periods for the Task 2 Rough Order of Magnitude (ROM) Analysis and the Task 3 Detailed Analysis. The Detailed Analysis resulted in the largest change in payback period for the advanced tip propellers. The smallest difference in payback period occurs for the advanced engine technologies.

Table 13. Comparison of Approaches Summary

Approach	Applicable Craft	Task 2 ROM Analysis Payback Period	Task 3 Detailed Analysis Payback Period
Stern Flap	87’ WPB	1.3 years	15+
Advanced Tip Propellers	87’ WPB	9.4 years	50+
Advanced Engine Technologies (Outboards)	RIBs	6.0 years	1.8
Waste Oil Disposal	All	1.2 – 19.0 years	--
Fuel Additives/Combustion Modifiers	All	0.4 –1.3 years	--

Recommendations

It is important to emphasize that the overall resistance reduction for an 87’ WPB equipped with stern flaps and advanced propellers will equate to reduce fuel consumption only if current operational speeds are maintained. The fact that the patrol speed is the best economic speed negates any possible fuel savings across 85 percent of the operational profile. The net effect would be a small increase in patrol speed. Furthermore, it is more likely that the potential fuel savings associated with operating 15 percent of the time at maximum speed will not be realized due to the nature of the USCG’s missions. The USCG tends to operate at maximum speed only when response time is critical and hence will trade the reduced fuel consumption for an increased maximum speed and decreased response time. Therefore, it is questionable whether retrofitting the 87’ WPB with advanced tip propellers and stern flaps will actually reduce the USCG’s fuel bill.

Based on the detailed cost analysis performed, replacing two-stroke outboard engines with more fuel-efficient four-stroke outboard engines will provide significant fuel savings. Further research is required before waste oil disposal systems and fuel modifiers should be considered for integration into the fleet as fuel-saving approaches.

This study evaluated the applicability and potential fuel savings of current technologies on the present USCG boat and small cutter fleet. To reduce fuel costs in future craft, fuel efficiency must be made a primary requirement and considered as a desirable feature to reduce total cost of ownership when evaluating proposed designs. The value of engineering dollars spent up-front to reduce fuel consumption should be considered in light of the life-cycle savings that could be gained. Beyond examining operational issues such as speed and range requirements that impact fuel consumption, the USCG should also evaluate alternative design philosophies in light of total cost of ownership. The use of composites or aluminum in the hull rather than steel is one such philosophy shift. Another alternative that may be cost effective in new construction is the use of auxiliary propulsion units, such as slow speed waterjets, to propel the craft while patrolling which allows the main engines to be used only when speed is demanded. Finally, the USCG should monitor closely the use of alternative fuels as this technology continues to mature and commercial applications increase.

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Appendices

Appendix A - Boat Designation List

RIB	Rigid Inflatable Boat (comprised of RIBM17, RIBM19, RIBM21)
21’ TAN	21’ Trailered Aids to Navigation Boat
24’ UTL	24’ Utility Boat Large
25’ UTL	25’ Utility Boat Large
41’ UTB	41’ Utility Boat
44’ MLB	44’ Motor Life Boat
47’ MLB	47’ Motor Life Boat
49’ BUSL	49’ Buoy Boat Stern Loader
55’ ANB	55’ Aids to Navigation Boat
64’ ANB	64’ Aids to Navigation Boat
65’ WYTL	65’ Yard Tug Large
65’ WLR	65’ River Buoy Tender
75’ WLIC	75’ Inland Construction Tender
75’ WLR	75’ River Buoy Tender
82’ WPB	82’ Patrol Boat
87’ WPB	87’ Patrol Boat
110’ WPB	110’ Patrol Boat

Appendix B - Stern Flap Sensitivity Data

Table B1. Acquisition/Install Cost per Vessel Alteration for Stern Flaps

Cost Function	Acquisition/Install Cost Per Vessel	Engineering/Design Cost Per Vessel	Number of Vessels	Cost Investment Per Class
Measurement	*dollars per vessel*	*dollars per vessel*		*dollars per class*
	$10,000	$115,000	50	$615,000
	$12,000	$115,000	50	$715,000
	$15,000	$115,000	50	$865,000
	$18,000	$115,000	50	$1,015,000
	$20,000	$115,000	50	$1,115,000

Table B2. SIR Calculations Altering Project Life for Stern Flaps

Interest Rate = 4%, Project Life = 10 Years

Discount Factor	Net Present Value (NPV) of Savings	Net Present Value (NPV) of Investment	SIR
8.1109	$599,524	$615,000	1.0
8.1109	$599,524	$715,000	0.8
8.1109	$599,524	$865,000	0.7
8.1109	$599,524	$1,015,000	0.6
8.1109	$599,524	$1,115,000	0.5

Interest Rate = 4%, Project Life = 15 Years

Discount Factor	Net Present Value (NPV) of Savings	Net Present Value (NPV) of Investment	SIR
11.1184	$821,825	$615,000	1.3
11.1184	$821,825	$715,000	1.1
11.1184	$821,825	$865,000	1.0
11.1184	$821,825	$1,015,000	0.8
11.1184	$821,825	$1,115,000	0.7

Interest Rate = 4%, Project Life = 20 Years

Discount Factor	Net Present Value (NPV) of Savings	Net Present Value (NPV) of Investment	SIR
13.5903	$1,004,536	$615,000	1.6
13.5903	$1,004,536	$715,000	1.4
13.5903	$1,004,536	$865,000	1.2
13.5903	$1,004,536	$1,015,000	1.0
13.5903	$1,004,536	$1,115,000	0.9

Interest Rate = 4%, Project Life = 25 Years

Discount Factor	Net Present Value (NPV) of Savings	Net Present Value (NPV) of Investment	SIR
15.6221	$1,154,720	$615,000	1.9
15.6221	$1,154,720	$715,000	1.6
15.6221	$1,154,720	$865,000	1.3
15.6221	$1,154,720	$1,015,000	1.1
15.6221	$1,154,720	$1,115,000	1.0

Interest Rate = 4%, Project Life = 30 Years

Discount Factor	Net Present Value (NPV) of Savings	Net Present Value (NPV) of Investment	SIR
17.292	$1,278,152	$615,000	2.1
17.292	$1,278,152	$715,000	1.8
17.292	$1,278,152	$865,000	1.5
17.292	$1,278,152	$1,015,000	1.3
17.292	$1,278,152	$1,115,000	1.1

Appendix C - 110' WPB/87' WPB Propeller and Sensitivity Data

Table C1. Propeller Curve Data for Three Propellers

Faired Open Water Coefficients
USCG Cavitation Propeller 5128 [1]
2/6/90 Exp. NO 1.00

J	K_T	10_{KQ}	ETAo
0.000	0.716	1.298	0.000
0.050	0.695	1.259	0.044
0.100	0.672	1.216	0.088
0.150	0.645	1.169	0.132
0.200	0.617	1.120	0.175
0.250	0.587	1.070	0.218
0.300	0.556	1.018	0.261
0.350	0.524	0.965	0.303
0.400	0.492	0.913	0.343
0.450	0.460	0.860	0.383
0.500	0.428	0.808	0.421
0.550	0.396	0.757	0.458
0.600	0.365	0.707	0.493
0.650	0.335	0.658	0.526
0.700	0.305	0.610	0.557
0.750	0.276	0.563	0.584
0.800	0.247	0.517	0.608
0.850	0.219	0.471	0.628
0.900	0.191	0.426	0.643
0.950	0.164	0.381	0.650
1.000	0.137	0.336	0.647
1.050	0.109	0.289	0.630
1.100	0.081	0.241	0.587
1.150	0.052	0.191	0.497
1.200	0.022	0.138	0.299

Predicted Open Water Coefficients
USCG 110' WPB Prop Design #4

J	K_T	10_{KQ}	ETAo
0.5	0.4277	0.71460	0.4701
0.6	0.3670	0.64780	0.5339
0.7	0.2975	0.54770	0.5972
0.8	0.2427	0.46470	0.6562
0.9	0.1863	0.38110	0.6910
1.0	0.1564	0.33510	0.6964
1.0	0.1289	0.29210	0.6934
1.1	0.0678	0.19300	0.6070

Regression Function Kt vs Ja and Kq vs Ja
USCG 87' Prop
BSI Propulsion Calcs

J	K_T [2]	10_{KQ} [3]
0.000	0.737	1.256
0.050	0.712	1.219
0.100	0.687	1.181
0.150	0.661	1.142
0.200	0.635	1.103
0.250	0.609	1.062
0.300	0.582	1.021
0.350	0.554	0.979
0.400	0.527	0.936
0.450	0.498	0.892
0.500	0.470	0.848
0.550	0.441	0.802
0.600	0.411	0.756
0.650	0.381	0.709
0.700	0.351	0.661
0.750	0.320	0.613
0.800	0.289	0.563
0.850	0.257	0.513
0.900	0.225	0.462
0.950	0.192	0.410
1.000	0.159	0.357
1.050	0.126	0.304
1.100	0.092	0.249
1.150	0.058	0.194
1.200	0.023	0.138

note:

1. = as obtained from the fax of Jessup concerning the Fleet Island Class Prop 5128 Open Water Data
2. = Kt = -0.08704*(Ja^2) - 0.49010*(Ja) + 0.73660
3. = 10KQ = -0.16403*(Ja^2) - 0.73494*(Ja) + 1.25613

Table C 2. Acquisition/Install Cost per Vessel Alteration for Advanced Propellers

Cost Function	Acquisition/Install Cost Per Vessel	Engineering/Design Cost Per Vessel	Number of Vessels	Cost Investment Per Class
Measurement	*dollars per vessel*	*dollars per vessel*		*dollars per class*
	$50,000	$60,000	50	$2,560,000
	$58,000	$60,000	50	$2,960,000
	$66,000	$60,000	50	$3,360,000
	$78,000	$60,000	50	$3,960,000
	$90,000	$60,000	50	$4,560,000

Table C 3. SIR Calculations Altering Project Life for Advanced Propellers

Interest Rate = 4%, Project Life = 10 Years

Discount Factor	Net Present Value (NPV) of Savings	Net Present Value (NPV) of Investment	SIR
8.1109	$723,563	$2,560,000	0.3
8.1109	$723,563	$2,960,000	0.2
8.1109	$723,563	$3,360,000	0.2
8.1109	$723,563	$3,960,000	0.2
8.1109	$723,563	$4,560,000	0.2

Interest Rate = 4%, Project Life = 15 Years

Discount Factor	Net Present Value (NPV) of Savings	Net Present Value (NPV) of Investment	SIR
11.1184	$991,858	$2,560,000	0.4
11.1184	$991,858	$2,960,000	0.3
11.1184	$991,858	$3,360,000	0.3
11.1184	$991,858	$3,960,000	0.3
11.1184	$991,858	$4,560,000	0.2

Interest Rate = 4%, Project Life = 20 Years

Discount Factor	Net Present Value (NPV) of Savings	Net Present Value (NPV) of Investment	SIR
13.5903	$1,212,373	$2,560,000	0.5
13.5903	$1,212,373	$2,960,000	0.4
13.5903	$1,212,373	$3,360,000	0.4
13.5903	$1,212,373	$3,960,000	0.3
13.5903	$1,212,373	$4,560,000	0.2

Interest Rate = 4%, Project Life = 25 Years

Discount Factor	Net Present Value (NPV) of Savings	Net Present Value (NPV) of Investment	SIR
15.6221	$1,393,627	$2,560,000	0.5
15.6221	$1,393,627	$2,960,000	0.5
15.6221	$1,393,627	$3,360,000	0.4
15.6221	$1,393,627	$3,960,000	0.4
15.6221	$1,393,627	$4,560,000	0.3

Interest Rate = 4%, Project Life = 30 Years

Discount Factor	Net Present Value (NPV) of Savings	Net Present Value (NPV) of Investment	SIR
17.292	$1,542,597	$2,560,000	0.6
17.292	$1,542,597	$2,960,000	0.6
17.292	$1,542,597	$3,360,000	0.5
17.292	$1,542,597	$3,960,000	0.4
17.292	$1,542,597	$4,560,000	0.3

Appendix D - Four-Stroke Outboard Sensitivity Data

Table D 1. Acquisition/Install Cost per Vessel Alteration for Four-Stroke Outboards

Cost Function	Acquisition/Install Cost Per Vessel	Engineering/Design Cost Per Vessel	Number of Vessels	Cost Investment Per Class
Measurement	*dollars per vessel*	*dollars per vessel*		*dollars per class*
	$500	$0	379	$189,500
	$1,000	$0	379	$379,000
	$1,750	$0	379	$663,250
	$2,500	$0	379	$947,500
	$3,000	$0	379	$1,137,000

Table D 2. SIR Calculations Altering Project Life for Four-Stroke Outboards

Interest Rate = 4%, Project Life = 1 Year

Discount Factor	Net Present Value (NPV) of Savings	Net Present Value (NPV) of Investment	SIR
0.9615	$261,345	$189,500	1.4
0.9615	$261,345	$379,000	0.7
0.9615	$261,345	$663,250	0.4
0.9615	$261,345	$947,500	0.3
0.9615	$261,345	$1,137,000	0.2

Interest Rate = 4%, Project Life = 3 Years

Discount Factor	Net Present Value (NPV) of Savings	Net Present Value (NPV) of Investment	SIR
2.7751	$754,300	$189,500	4.0
2.7751	$754,300	$379,000	2.0
2.7751	$754,300	$663,250	1.1
2.7751	$754,300	$947,500	0.8
2.7751	$754,300	$1,137,000	0.7

Interest Rate = 4%, Project Life = 5 Years

Discount Factor	Net Present Value (NPV) of Savings	Net Present Value (NPV) of Investment	SIR
4.4518	$1,210,043	$189,500	6.4
4.4518	$1,210,043	$379,000	3.2
4.4518	$1,210,043	$663,250	1.8
4.4518	$1,210,043	$947,500	1.3
4.4518	$1,210,043	$1,137,000	1.1

Interest Rate = 4%, Project Life = 7 Years

Discount Factor	Net Present Value (NPV) of Savings	Net Present Value (NPV) of Investment	SIR
6.0021	$1,631,430	$189,500	8.6
6.0021	$1,631,430	$379,000	4.3
6.0021	$1,631,430	$663,250	2.5
6.0021	$1,631,430	$947,500	1.7
6.0021	$1,631,430	$1,137,000	1.4

Interest Rate = 4%, Project Life = 10 Years

Discount Factor	Net Present Value (NPV) of Savings	Net Present Value (NPV) of Investment	SIR
8.1109	$2,204,623	$189,500	11.6
8.1109	$2,204,623	$379,000	5.8
8.1109	$2,204,623	$663,250	3.3
8.1109	$2,204,623	$947,500	2.3
8.1109	$2,204,623	$1,137,000	1.9

Appendix E - Request for Information (RFI) via CBD

U.S. Government Procurements: Supplies Ships and Marine Equipment – Potential Sources Sought

Naval Surface Warfare Center, Carderock Division, 9500 MacArthur Blvd., West Bethesda, MD 20817-5700

07-14-00 CBD#291 20 – POTENTIAL SOURCES SOUGHT – ADDITIVES TO REDUCE FUEL CONSUMPTION POC Mr. David Pogorzelski (757) 686-7304/ PogorzelskiDA@nswccd.navy.mil. Naval Surface Warfare Center, Carderock Division (NSWCCD),

Detachment Norfolk is conducting a survey of potential suppliers of additives that reduce fuel consumption. This is not a solicitation but a request for information. The information requested is for additives specifically capable of reducing the Marine Grade Diesel fuel consumption of engines manufactured by various companies. Information on additives capable of reducing the fuel consumption of gasoline powered outboard engines is also of interest. The following data is requested: additive description, maturity, marine engine compatibility, cost, maintenance impact, and availability. Copies of independent test data should also be included. A response to this announcement is not a prerequisite for participation in any future craft program should such a program develop. Also, data provided will not be used to qualify prospective offerors for any future solicitations. NSWCCD will not pay or provide reimbursement for any costs incurred in the preparation of delivery of the requested information. Providers of the request information are asked to respond within 14 days of the announcement. Responses shall be submitted to Naval Surface Warfare Center, Carderock Division, Detachment Norfolk, 116 Lake View Parkway, Suite 200, Suffolk, Virginia 23435-2698 Attn: David Pogorzelski (Code 2311).